Seismic Hazards of Puget Sound (SHIPS): Collaborative Research with U.S. Geological Survey, Oregon State University & University of Texas at El Paso, University of British Columbia, University of Washington, University of Victoria, Pacific Geo-science Center

Annual Project Report
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Element I - Evaluating National and Regional Hazard and Risk

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Abstract

The heavily populated Puget Basin is underlain by thick sequences of Cenozoic sedimentary rocks that amplify and focus seismic energy, thus increasing ground shaking during an earthquake. The SHIPS (Seismic Hazards Investigations of Puget Sound) project is targeted at acquiring and analyzing controlled source seismic data to be used in modeling and mapping areas of expected strong ground shaking and at better determining the regional velocity structure and tectonic framework of the Puget Sound region, including the location, configuration, and seismic properties of faults that cross this urban region. This project represents the first phase of SHIPS. Data were acquired during March 1998, and include marine multichannel seismic data, expanding spread profiles, and ocean-bottom on onshore/offshore large-aperture recording of marine air gun shots. A total of some xx GBytes were recorded and have been submitted to the IRIS data management center. Work at Oregon State University has focused on the structure beneath the Straits of Juan de Fuca and beneath the core of the Olympic Mountains, and precisely defines deformation of the sub ducting plate where it bends sharply to the north. This study also provides new constraints on deformation of the overriding plate and on the evolution of plate boundary reflectivity. While this region is west of the zone of greatest earthquake activity, understanding the deformation here is critical for tying the structure beneath Puget Sound to

that beneath the well-imaged continental margin and for interpreting the tectonic causes of seismicity further east.

A preliminary 2-dimensional model of the crust and upper mantle, including the region of the Juan de Fuca/North America plate boundary, was presented at the Fall, 1998, meeting of the American Geophysical Union. This model was refined somewhat and presented at the spring 1999 meeting of the Seismological Society of America. A second presentation at that meeting compared the results to results of similar studies elsewhere along the Cascadian sub-duction zone. This work was expanded to a 3-dimensional model of the upper crust beneath the Straits of Juan de Fuca and a model of the Moho of the sub ducting plate beneath a larger region for the fall, 1999, AGU meeting. In this study, the Moho of the Juan de Fuca plate is a proxy for deformation of the plate as a whole. We are currently in the process of preparing these results for publication.

Work accomplished in FY99:

During FY98, data were acquired and previewed. The dataset recorded on stations deployed by Oregon State University on the Olympic Peninsula included -1000 record sections from shots in the Straits of Juan de Fuca, Straits of Georgia, and Puget Basin(figure 1). Examples of data were included in the FY98 Project Report. In FY99, we modeled those data, first constructing a 2-D model of crustal structure along the Straits of Juan de Fuca (Trehu et al., 1998; Trehu et al., 1999a), and then expanding this model to a 3-D model of the upper crust beneath the Straits of Juan de Fuca and a larger-scale 3-D model of the Moho of the sub ducting Juan de Fuca plate beneath Vancouver Island, the Straits of Juan de Fuca and the Olympic Peninsula. We have also processed the multi-channel seismic reflection data along the Straits of Juan de Fuca.

Figure 1. Map showing the locations of sources and receivers during the SHIPS98 experiment. Black squares are REFIEK stations used to date in this project. Black shot lines show shots used to date. Multi-channel seismic profiles JDFI and JDF2 have been processed to illuminate deep crustal reflectivity beneath the Straits of Juan de Fuca, The smaller white box delimits the boundaries of the 3-D first arrival tomographic model that is shown infigure 2.

Figure 2 shows the working 3-D model of upper crustal structure beneath the Straits of Juan de Fuca. This most important feature to point out in this model is the deep, linear Clallam basin beneath line JDF2. This basin is not present beneath JDFI, along the Canadian margin. The short wavelength and linear nature of this basin, which is parallel to the contours of the sub ducting plate (see next paragraph) suggests that it is formed by deformation of the overriding plate resulting from interplate interaction. In early FY2000, we will expand this model to include first arrival times recorded at stations distributed throughout Vancouver Island, better defining this upper plate deformation.

Figure 3 shows our working 3-D model for the Moho of the sub ducting Juan de Fuca plate. This model was constructed by a 2-stage process in which clear secondary arrivals interpreted to be PmP after consideration and elimination of other possible sources were corrected to 10 kilometers depth in order to adequately account for complicated shallow structure in a model appropriately parameterized for the large-scale but less detailed deep structure. The correction was obtained by calculating the travel time through the top 10 km of the model descriped in the previous paragraph beneath all shots in the Straits of Juan de Fuca and through the 10 km of the model derived by Brocher et al. (1999) for the Puget Basin. We have been using the same coordinate system for our as modeling as is used by Brocher et al. (1999) in order to facilitate collaboration. This model confirms earlier inferences based on seismicity of an arch in the plate beneath the Olympic Peninsula and puts precise limits on the curvature of the arch and the depth to the active plate boundary.

The models in figure 2 and 3 enable us to define the relationship between crustal reflectivity and plate boundary structure imaged in the multi-channel seismic data along the Straits of Juan de Fuca. These models indicate that the "F" reflection is the base of the crust of the sub ducted Juan de Fuca plate and that the "E" band of high reflectivity is upper oceanic crust of the Juan de Fuca plate and overlying sedimentary or fluid charged strata. The active plate boundary must fall within this zone. The lack of a single clear reflection suggests that the active plate boundary here is a distributed shear zone. Because the reflection data in the Straits of Juan de Fuca can, in turn, be correlated with Litho probe data from Vancouver Island, we suggest that the current Litho probe interpretation of the "F" reflections as the plate boundary and the "E" reflections as a relict zone of under plating should be reconsidered.

In summary, the SHIPS results provide unprecedented detail about deformation of the sub ducting plate as it accommodates a major change in the trend of the plate boundary. This information can be used to contrain models for intraplate stresses in this region of focused seismicity that underlies a heavily populated region. The data also permit us to reevaluate models based on seismic reflection of the position and character of the interplate boundary zone.

Publications supported by this grant during FY99:

Trehu, A.M., R.S. Azevedo, C. Craven, D.M. Childs, T.M. Brocher, M.A. Fisher, 1998, Juan de Fuca/North America plate boundary beneath the Straits of Juan de Fuca and Olympic mountains from SHIPS, EOS, Trans. Am. Geophys. Un. 1998 fall meeting, p. F898.

Coauthor on 3 additional SHIPS abstracts at 1998 fall AGU meeting.

Trehu, A.M., T.M. Brocher, M.A. Fisher, T. Parsons, R.D. Hyndman, G. Spence, 1999, Structure and reflectivity of the sub ducting Juan de Fuca plate beneath the Straits of Juan de Fuca and northern Olympic peninsula, Seis. Research Let. v. 70, p. 254.

Trehu, A.M., and 15 others, 1999, Structure of the Cascadian sub-duction zone from seismic reflection and
Re-fraction data: relationship to seismic activity, Seis. Res. Let. v. 70, p. 209. (Invited overview).

Coauthor on 3 additional SI-HPS abstracts at 1999 spring SSA meeting.

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Scherer, H., A. M Trehu, T.M. Brocher, M.A. Fisher, T. Parsons, The Juan de Fuca plate beneath the Olympic Peninsula, EOS. Trans. Am. Geophysics. Un. SHIPS special session. (Presented by Trehu. Scherer was IRIS undergraduate intem at Oregon State Un. during summer, 1999)

Coauthor on 6 additional SHIPS abstracts at 1999 fall AGU meeting.

Trehu et al., The shape of the Juan de Fuca plate beneath the Olympic Peninsula, in preparation for Geology.

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